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TITLE: FMIT DIRECT-CURRENT BEAM MONITOR

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FMIT DIRECT-CURRENT BEAM MONITOR*

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Introduction

The prototype injector section for the Fusion Materials Irradiation Test (FMIT) Facility being developed at the Los Alamos National Laboratory requires that beam parameters be noninterceptively monitored. This report describes the application of a single toroidal core, coupled with very simple circuitry, that results in the production of a simple instrument, and eliminates the problems inherent in the Faraday cup technique for the current measurements of the FMIT injector beam.

A single toroidal core, fitted about the injector beamline, will noninterceptively couple to the beam current by magnetic induction, allowing a quantitative measurement of that current over a range of 0.5 to 100 mA, with an expected 0.05% linearity. The sensor electronics are based on the second harmonic modulation technique, and have benefited from similar devices reported from CERN[1] and LLL[2]. The prototype design allows the user a choice of current-readout modes (that is, analog or digital), as well as a fiber-optic link drive for remote computer acquisition.

Theory of Operation

To acquire a linear, secondary, output-sense current from the toroidal winding L-1 (Fig. 1a) as a function of the applied input primary current (injector beam), it is essential to operate within the core's linear saturation region. This linear saturation region is illustrated on the B-H profile as point "A" for beginning-core saturation, and point "B" for upper level saturation (Fig. 1c). In our experimental monitor, we are using a 0.1-mm-thick, tape-wound core of Permalloy square 80 material.

A bipolar, stabilized, square-wave current waveform, operating at ~600 cs, is applied to the principal toroid winding L-1 (Fig. 1a). This modulating waveform (Fig. 1b) drives the core (at the flat-topped peaks) to the first saturation-level point "A" (Fig. 1c). If the driving amplitude (for a given core material) should be insufficient to reach the initial saturation level "A", a second winding (bias) L-2 is wound over L-1 and is supplied with an appropriate constant current sufficient to reach this saturation level. In practice, we have found that just a few milliamperes is adequate to reach this level. From this point on, further current applied to the primary (injector beam) will continue to saturate the core linearly towards the upper-level saturation point "B". This linear saturation region, points "A" to "B" (linear saturation rise) corresponds to a linear decrease in the inductance of L-1. A small rectifying component of the modulating frequency is fed back on winding L-4 to allow a stabilizing feedback to the linear operational point, "C".

Circuit Function

The electrical block diagram for the current monitor is shown in Fig. 2. The ac signal developed by the toroid L-1 is applied to the input of a precision, full-wave rectifying circuit through a narrow-band (10 c/s) filter to the inverting input of the chopper-stabilized operational amplifier. To eliminate the possible hetrodyning conflict that might exist between the amplifier's chopping frequency and the 600-c/s ripple of the system driving frequency, we interposed the filter as a precautionary measure. In retrospect, a simple RC network may be just as effective.

In view of the low-level dc offset voltages that must be amplified, very deliberate care must be exercised in the selection of high-quality, low-drift, operational amplifiers, passive components, and attention to circuit-board layouts, all in an effort to minimize the drift problems inherent with direct coupled systems. Conditioning the air within the compartment housing the circuit boards will measureably improve the overall stability of the circuits discussed. Several high-quality operational amplifiers were evaluated for this application, and most were found to be satisfactory. In the final analysis, and with the intentions of further improving on the long-term stability of the monitor, we decided in favor of the chopper-stabilized amplifiers.

Toroid Driver

A modified Wien bridge oscillator, operating at a stabilized frequency of ~600 c/s, generates a 28-V peak-to-peak, square wave (50% duty cycle) with an excellent flat-topped characteristic of less than 1% droop. The output of the square wave generator is applied to a pair of emitter followers which in turn provide a constant current drive to the toroidal core L-1. The emitter follower drivers are optimally biased

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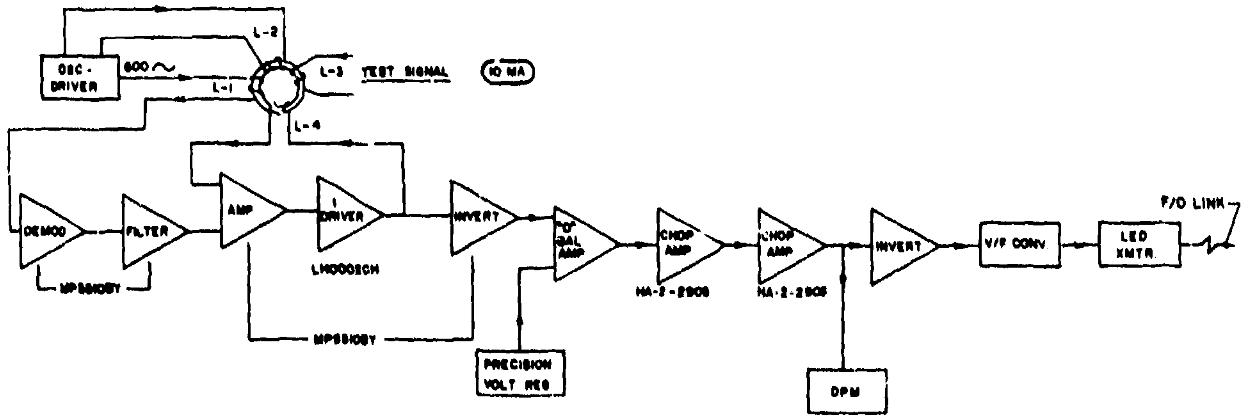

Fig. 1. Schematic for transducator operation.

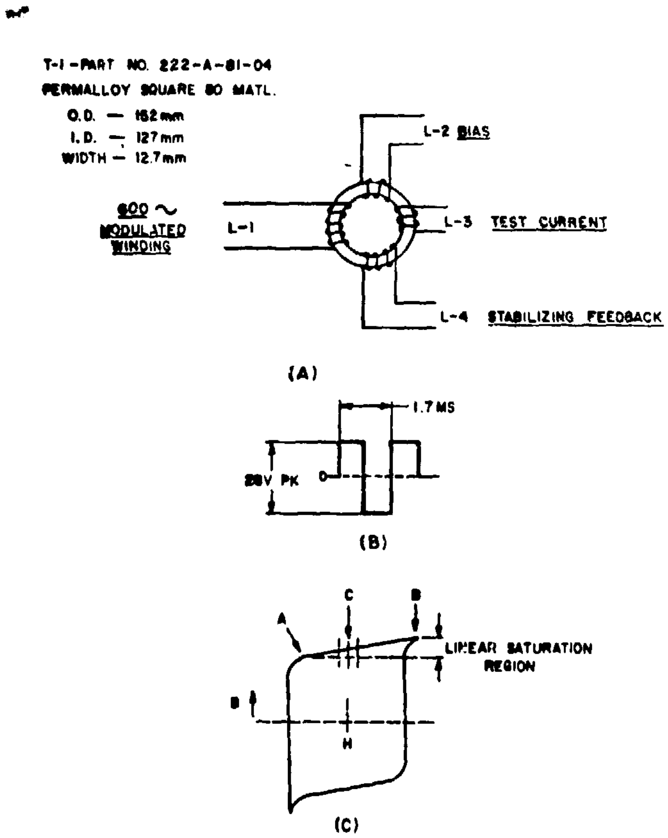

Fig. 2. Electronics block diagram.

for minimum crossover distortion. The driver's output-amplitude stability is maintained by high-level feedback to the amplifier of the oscillator driver.

Toroidal Core

The toroidal core used in the prototype monitor measures 127-mm ID x 152-mm OD and is 12.7 mm wide. The core-grade, Permalloy square 80 is tape-wound with 0.1-mm-thick laminate and is aluminum encased. The major winding (L-1) consists of approximately 308 turns of #26 Permalese-coated magnetic wire, wound over 95% of the core's toroidal length, with a separation between turns of roughly one wire diameter. The bias winding (L-2) and the test-signal winding (L-3), each six turns, are wound over the full length of the major winding. Each winding is terminated into 46-cm-long, color-coded, pigtailed leads. To stabilize the windings, the core is immersed in Dow Sylgard 182. This immersion process is performed several times, the core being allowed to dry between immersions. This process is performed as many times as necessary, until a coating 0.1-0.25 mm thick is achieved. The encapsulated core is then fitted with an outer electromagnetic shield.

Instrument Description

The initial packaging style of the monitor was influenced by factors such as circuit function isolation, ease of fabrication, field maintenance, and system cooling. The functional electronic circuits are divided into three separate printed circuit boards. These three system boards and two plug-in type, power-supply modules are mounted on a hinged subchassis and installed at the center (inner) location of the main case. A 6.35-cm cooling fan is attached at one end of the case, to allow uniform airflow over both sides of the circuit boards. The front panel is horizontally hinged to allow easy access to the circuit boards. The case is made of lightweight aluminum measuring 15.24 cm x 20.3 cm x 38 cm, and will be wall-mounted adjacent to the beamline.

References

1. K. Unser, ISR Division, CERN, private communication, 1980.

2. R. Rathjen, Lawrence Livermore Lab., private communication, 1980.